Soil Nitrogen Status of Larch Plantations in Comparison with Secondary Broad-leaved Forest[1]

Cui Xiaoyang (崔晓阳)
Northeast Forestry University, Harbin 150040, P. R. China
Zheng Guoqing(郑国庆)
Heilongjiang Research Institute of Forest Management , Harbin 150040, China

Abstract Soils were collected from three neighboring forest sites: 36-year-old larch plantation, 11-year-old larch plantation, and natural secondary broad-leaved forest (as control). Soil pH, total C, total N, C/N ratio, and available N (NO_3-N and NH_4-N) were measured. Laboratory incubations of soil samples were conducted during a 50 days period for the measurement of nitrogen mineralization rate and nitrification potential. The results proved a degeneration in soil nitrogen status with stand age of larch plantations, which implicated one important aspect of soil degradation when natural forest was replaced by coniferous plantations.

Key words: Larch plantation, Secondary broad-leaved Forest, Soil, Nitrogen

Introduction

Soil degradation of southern Chinese fir (*Cunninghamia lanceolate*) plantations have been Continually reported (Shen Weitong 1992; Chen Binghao 1992; Fang Qi 1992). In the northeast forest regions of China, larch (*Larix olgensis* and *Larix gmelinii*) plantations made 70 percent of the man-made forests, and the changes in soil properties under the coniferous plantations have also drawn much attention of many foresters. Our objective was to examine the difference in soil nitrogen status between Larch plantations and secondary broad-leaved forests (as control), which might be indicative of soil degradation in larch plantations.

Materials and Methods

In the Maorshan Experimental Forest Farm of Northeast Forestry University, three neighboring sites were selected: 36-year-old larch plantation, 11-year-old larch plantation, and natural secondary broad-leaved forest (birch dominant). Soils on all sites are Dark Brown Forest Soil. At each site nine replicate plots, 55 m, were established. Soils were sampled one time at the beginning of growing season (10th, May). For each replicate plot surface soils were randomly sampled to a depth of 20 cm (A horizon), and a single composite soil sample consisting of five individual samples was collected. Samples were moist sieved to < 5 mm, and chemical analyses was made immediately.

Soil NH_4-N and NO_3-N Concentrations were determined with (M KCl in a 10:1 extractant-to-soil ratio, and soil pH was determined in 1:1 soil-water solution (Air) dried soil samples were used for total N analyses (Auto-Kjeldahl method) and total C determination ($K_2Cr_2O_7$-oxidation method).

Aerobic incubations were conducted on soil samples with the sand/soil mixture method outlined by Keeney and Bremner (1967). Soil(100~150 g) was mixed with acid-washed sand in a 1:3 soil/sand ratio, brought to 20% (W/W) moisture content, and placed in acid-washed Nalgene containers. Containers were covered with plastic wrap and placed in a dark incubator at 25 °C. During incubation subsamples of the sand/soil mix were removed to determine NH_4-N and NO_3-N. Determinations were made after incubation periods of 3, 5, 10, 15, 20 and 30 to 50 days. The moisture content of the incubation material (sand/soil mixture) was readjusted at each subsample removal.

The nat N mineralization rate (i.e, the release of in-

[1] The study was supported by the Chinese Natural Science Fundation (39770608)

organic N during incubation) was calculated as the difference in the concentration of inorganic N(NO_3-N+NH_4-N) at the beginning and end of the laboratory incubation divided by the number of days the soil was incubated. Patterns of nitrification were expressed mathematically for all incubated samples. The NO_3 concentration was described as a function of incubation time by either a second or third-order equation, using the stepwise procedure to select the relationship which provided the best fit to the data. Theoretically, the relationship between NO_3 production and incubation time should present a sigmoidal curve (third-order equation). However, the incubation period was insufficient to obtain this curve shape for all samples, and in some cases, a second-order equation resulted. The mathematical function for each soil sample incubation was used to calculate three parameters describing the sample's potential to produce NO_3: (1) the maximum rate of nitrification (for the second-order equations, this was equal to the maximum slope of the NO_3-production curve; for the third -order equations, the maximum rate was the slope at the inflection point of the curve); (2) the lag in nitrification (defined as the x-intercept of the maximum-rate line); (3) the initial rate of nitrification (the slope of a line describing NO_3 levels between t=0 and t=lag time) Fig. 1 and 2 illustrate these parameters for second-and third-order relationships, respectively.

Results and Discussion

Soil chemical analyses

Chemical analyses data were generally used to characterize soil nutrient status of forest site. There was no significant in soil total C content among the three sites; however, the C/N ratio was significantly higher on the 11-year-old larch site than that of secondary broad-leaved forest, and much more high on the 36-year-old larch site, which led in successive decrease in soil total N content with the increase in larch plantation age (Table 1, Column 4). Larch plantations, however younger (11years) or elder (36 years), brought down the soil NO_3-N level very rapidly (Table 1, column 6). Owed to the larger buffer capacity of cation(offered by soil colloid, the NH_4-N concentration varied relatively more gentle (than NO_3-N) among different sites, but still differed from each other significantly, presented a successive decrease with the increase in larch plantation age (similar to total N).

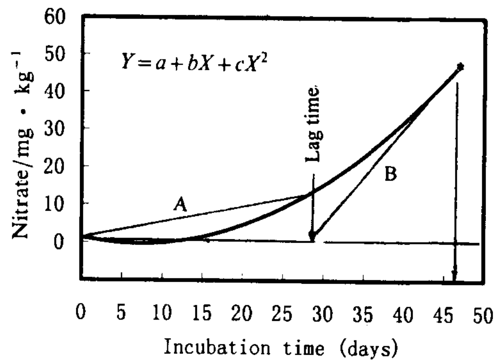

Fig. 1. Second-order relationship between soil NO_3 concentration and incubation time.

Maximum rate of NO_3 production is dedicated by * Slopes A and B represent initial and maximum nitrification rates, respectively The x intercept of the maximum-rate slope (B) is defined as the lag in nitrification Adapted from J.M. Donaldson and G.S. Henderson (1990).

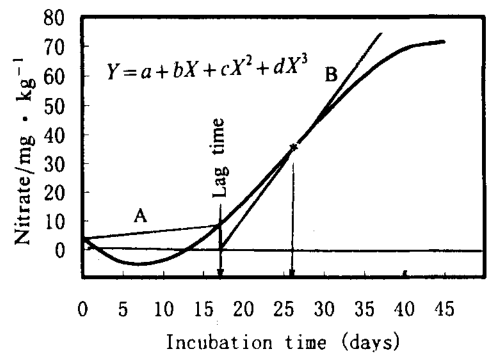

Fig. 2. Third-order relationship between soil NO_3 concentration and incubation time.

Maximum rate of NO_3 production is indicated by * Slopes A and B represent initial and maximum nitrification rates, respectively The x intercept of the maximum-rate slope (B) is diffident as the lag in nitrification Adapted from J.M. Donaldson and G.S. Henderson(1990).

Table 1. Soil chemi-nutrient data for three forest sites, average of nine replicate plots.

Site	Soil pH	Total C (%)	Total N (%)	C/N ratio	Available N (mg•kg^{-1})	
					NO_3-N	NH_4-N
36-year-old larch plantation	5.02a[1)]	5.83A	0.345a	16.89c	1.20a	18.45a
11-year-old larch plantation	5.54b	6.03A	0.423b	14.89b	1.23a	28.70b
Secondary broad-leaved forest	5.57B	6.28a	0.480c	13.08a	4.19b	33.70c

1) Within columns, means followed by the same letter are not significantly different at 0.05 level

Nitrogen mineralization rate and nitrification patterns

The rate of release of inorganic N during laboratory incubation (N mineralization rate) reflects the potential availability of nitrogen to plants, thus, it should be a better index of evaluating soil nitrogen status. This rate differed significantly among sites, i.e. successively depressed under larch plantations with stand age (Table 2). There exists a coincidence in total N content. N mineralization rate, and NH_4-N content among sites (Table 1, column 4; Table 2, column2; Table 1, column 7).

Table 2. Soil nitrogen mineralization rate and nitrification indices of three forest sites, average of nine replicate plots.

Site	N mineralization rate /$mgN \cdot kg^{-1} \cdot d^{-1}$	lag in nitrification (d)	Nitrification rate /$mgNO_3$-$N \cdot kg^{-1} \cdot d^{-1}$	
			Initial	Max
36-yr-old larch plantation	1.21a[1)]	21b	0.38a	1.67a
11-yr-old larch plantation	1.66b	19b	0.53b	2.10b
Secondary broad-leaved forest	2.13c	11a	0.77c	3.12c

1) Within columns, means followed by the same letter are not significantly different at 0.05 level

The three variables mathematically derived form the NO_3-N production data describe the potential of nitrification of soils. Larch plantation sites showed much longer lag periods than the natural secondary broad-leaved forest site (Table 2). The initial and maximum rate of NO_3-N production during soil incubations varied significantly among sites too, and demonstrated successive decrease with larch plantation age (Table 2). Donaldson and Hendersont (1990) found that soil pH and NH_4-N levels were the two major soil properties controlling lag period and initial nitrification rate during laboratory incubations, and our study also revealed a coincidence of nitrification rate (initial and maximum) with soil pH and NH_4-N levels among different sites (Table 2, column 4, column 5: Table 1, column 2, column 7).

Some authors (Popovic 1980; Pavl and Juma 1981; Burger and Pritchett 1984) have pointed out that laboratory incubations may not truly depict field processes. Even so, the results for different sites remained comparable under the same incubation conditions.

Concluding Remarks

From the results we conclude that the soil nitrogen status degenerated under the influence of larch plantation, which implicated one important aspect of soil degradation when natural forest was replaced by coniferous plantations.

Coniferous trees generally contain larger amount of resins, tannins and polyphenolic compounds than broad-leaved species. These high-molecular-weight compounds are resistant to decomposition, or may inhibit N-mineralizing or NH_4-oxidizing bacteria. These compounds are added to the litter layer and soil, and accumulate in the soil organic matter (Lamb 1980). This accumulation increases the C/N ratio of the litter and soil organic matter, and consequently further decreases N availability to plants (Donaldson and Henderson 1990). Soil pH also affects nitrogen mineralization and nitrification, under acidity conditions the two processes of nitrogen release would be generally restricted, and the available N (NO_3-N and NH_4-N) level lowered.

References

Burger, J.A. and W.L. Pritchett. 1982. Effects of clearfelling and site preparation on nitrogen mineralization in a southern pine stand. Soil Sci. Soc. Am. J. 48: 1432-1437.

Donaldson, J.M. and G.S. Henderson. 1990. Nitrification potential of secondary-succession upland oak forest: I. Mineralization and nitrification during laboratory incubations. Soil Sci. Soc. Am. J. 54: 892-897.

Keeney, D.R. and J.M. Bremner. 1967. Determination and isotope ratio analysis of different forms of nitrogen in soils: 6. Mineralizable nitrogen. Soil Sci. Soc. Am. Proc. 31: 34-39.

Lamb, D. 1980. Soil nitrogen mineralization in a secondary rainforest succession. Oecologia 47:257-263.

Paul, E.A. and N.G. Juma. 1981. Mineralization and immobilization of soil nitrogen by microorganisms. in F.E. Clark and T. Rosswall (ed.) Terrestrial nitrogen cycles processes, ecosystem strategies and management impacts. Ecol. Bull. 33: 179-185.

Popovic, B. 1980. Mineralization of nitrogen in incubated soil samples from an old Scots pine forest. in T. Persson (ed.) Structure and function of northern coniferous forests-An ecosystem study: Ecol. bull. 32:411-418

(**Responsible Editor:** Chai Ruihai).